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(54) **Apparatus for dislodging or loosening mucus in a person's lungs**

Vorrichtung zur Beeinflussung der Lunge zur Schleimlösung

Dispositif servant à decoller le mucus dans les poumons

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**EP-A- 0 651 987** **US-A- 3 550 586**  
**US-A- 3 955 563** **US-A- 4 216 766**

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## Description

[0001] This invention relates to the dislodging or loosening of mucus in a person's lungs.

[0002] Cystic fibrosis is an inherited disease which damages vital organs, especially the lungs and pancreas, by clogging them with mucus. Drugs exist which can ameliorate its effects, but physical management of the disease is nevertheless very important.

[0003] Mucus is continually produced in the lungs and keeps the airways moist. Particles of dust, dirt or bacteria lodge in the mucus, which is cleared in the healthy lung and swallowed. This process happens all the time and is the way that the lungs keep themselves clear and free of infection.

[0004] The mucus produced by cystic fibrosis suffers contains less water than it should and hence is sticky. As a result, the process of cleaning of the lungs is inefficient or absent leading to build-up of bacteria, dirt and mucus in the lungs. Infection as a result is more likely.

[0005] Current physical management relies on using motion of the lungs to dislodge mucus. This can be induced by controlled breathing, and by shaking or clapping of the front, back and/or sides of the chest with the hands. The mechanism by which motion causes clearing of the lungs is not completely understood, but it is probable that it is at least partly because mucus is a thixotropic fluid, that is, one which becomes more fluid when vibrated.

[0006] Physical movement of the chest by means of clapping or shaking is likely to be a very inefficient way of causing vibration of the lungs, since the chest wall will resist movement. It is labour intensive and usually requires a partner to administer. In addition, it has to be carefully taught and practised, since the possibility exists of injury if administered too forcefully. This is particularly important in young children and babies who may be unable to give any indication as to its acceptability.

[0007] This invention relates more particularly to an apparatus for dislodging or loosening material in a person's lungs, comprising a bath arranged to receive the person and a liquid such that the person's chest is immersed in the liquid, and means for vibrating the liquid so that the vibrations are transmitted to the person's lungs. Such an apparatus is disclosed in patent document US-A-4216766. Additionally, this known apparatus comprises means for detecting a level of vibrations to produce a detection signal, and means for attaching the detecting means to the person's chest so as to detect a level of vibrations transmitted to the person's lungs. The frequency of vibration is set using a control device at a resonant frequency of the person's lung cavity.

[0008] Sound in water may be used to stimulate the lungs in an efficient and controllable manner. Sound in water interacts with the body much more strongly than sound in air due to the similar physical properties of wa-

ter and body tissue. Sound in water may easily pass into and out of the body.

[0009] When a body immersed in water is subjected to sound, the lungs can become resonant and vibrate strongly. This is because the lungs contain air and can store potential energy when the air is compressed. Also, the water next to the chest acts as a mass, which can store kinetic energy. As a result, a fundamental pulmonary resonance exists, typically at a frequency of about 80 Hz, for the submerged body exposed to sound. At higher frequencies, higher order resonances of the lungs may occur, for instance where one lung is compressing as the other lung is contracting. At high enough frequencies, resonances of other air containing structures of the body may occur. However, no equivalent vibratory resonance occurs in the non air containing structures of the body, and hence the possibility exists of using this property of sound to vibrate the lung selectively through selection of the correct frequency of the sound, thus enabling relief for sufferers of cystic fibrosis.

[0010] Furthermore, it has been found that there additionally exists a Helmholtz resonance of the lungs at a frequency of about 16 Hz in a submerged adult, and correspondingly higher for a child, involving the compressibility of the air in the lungs and the mass of air in the airways and the mass of the water around the chest. At this frequency, a strong resonance of the lungs may be excited, with oscillatory flow of air in the airways, into and out of the lungs occurring along with a large displacement of the lungs and chest wall. This resonance consequently may also may be very beneficial in dislodging mucus.

[0011] The present invention seeks to provide an improved apparatus as compared with that cited above, which comprises means (such as a liquidproof accelerometer) for detecting a level of vibrations to produce a detection signal, means for attaching the detecting means to the person's chest so as to detect a level of the vibrations transmitted to the person's lungs, and which is characterised by means responsive to the detection signal for automatically adjusting the frequency of the vibrations produced by the vibrating means so that the frequency of the vibrations approximates a resonant frequency of the person's lungs and so as to maximise the level of the detected signal. Accordingly, the apparatus can automatically set the frequency so as to produce resonance in the lungs of the person being treated.

[0012] The adjusting means may be arranged to adjust the frequency of the vibrations to the pulmonary resonant frequency of the person's lungs, which may be in the range of 40 to 160 Hz. Alternatively, the adjusting means may be arranged to adjust the frequency of the vibrations to the Helmholtz resonant frequency of the person's lungs, which may be about 16 Hz for an adult and correspondingly higher for a child.

[0013] The vibrating means is preferably disposed, in use, in front of or behind the person's chest.

[0014] The vibrating means may be disposed inside

the bath. Alternatively, it may be disposed outside the bath and be arranged to transmit the vibrations to the liquid through a wall of the bath.

[0015] The bath may be arranged so that the person can sit up in the bath, with the vibrating means being disposed to one side of the bath. Alternatively, the bath may be arranged so that the person can lie in the bath, with the vibrating means being disposed at the bottom of the bath.

[0016] Specific embodiments of the present invention will now be described, purely by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a block diagram of a vibration generating system; and

Figures 2 to 5 are schematic diagrams of various embodiments of the apparatus.

[0017] Referring to figure 1, a first arrangement of the vibration generating system comprises an electro-mechanical transducer or vibrator 10, a driver circuit 12 for supplying an excitation signal to the vibrator 10 and a manual selector 14 for setting the frequency of the excitation signal in the range of, for example, 40 to 160 Hz. An automatic frequency control ("AFC") circuit is placed between the manual selector 14 and the driver circuit 12. Also, a waterproof accelerometer 22 is attached, for example by straps, to the chest of the person and supplies a signal to the AFC circuit 20. The excitation signal initially has a frequency set by the selector 14, but the AFC circuit 20 adjusts the frequency of the excitation signal so as to maximise the level of the signal received from the accelerometer 22.

[0018] Figure 2 shows an embodiment of the apparatus comprising a bath 24 having a seat 26 on which a person 28 sits. The bath 24 contains water 30 up to the neck level of the person 28. The side of the bath in front of the person 28 has a recess 32 containing a waterproof moving-coil loudspeaker 34, which provides the vibrator 10 of figure 1. The axis of the loudspeaker 34 is directed generally towards the chest of the person 28.

[0019] Figure 3 shows a modification to the embodiment of figure 2, in which the loudspeaker 34 is self contained and is mounted on a shelf 36 in the bath 24.

[0020] Figure 4 shows a further modification of the embodiment of figure 2 in which a portion 38 of the wall of the bath 24 facing the chest of the person 28 is movable and can be vibrated by a moving coil arrangement 40 so as to provide the vibrator 10 of figure 1.

[0021] Figure 5 shows a further modification of the embodiment of figure 2, in which a membrane 42, for example of rubber, is disposed in front of the loudspeaker 34 so that the loudspeaker need not be waterproof.

[0022] It will be appreciated that many modifications and development may be made to the embodiments described above. For example, the vibrator 10 may be disposed behind, rather than in front of, the person 28. Fur-

thermore, a pair of vibrators 10 may be employed in front of and behind, respectively, the person 28 and may be driven in parallel. Also, the bath 24 may be arranged so that the person lies in the bath, supine or prone, rather than sits in it, and the vibrator 10 may be disposed at the bottom of the bath so as to direct vibrations upwardly to the chest of the person 28. Accordingly, a vibrator 10 may be placed on the bottom of a conventional domestic bath in order to provide the benefits of the invention.

[0023] In the embodiments described above, a frequency range of 40 to 160 Hz has been mentioned in order to excite a pulmonary resonance. Alternatively or additionally a frequency of about 16 Hz, or a range from about 16Hz upwards may be employed in order to excite a Helmholtz resonance of the person's lungs.

[0024] In the embodiments described above, the vibrator 10 is provided by a moving coil device. Other transducers may be used, such as piezoelectric devices, pneumatic devices or rotary motor driven devices.

[0025] It should be noted that the embodiments of the invention have been described purely by way of example, and that many other modifications and developments may be made thereto, without departing from the scope of the invention as defined in the appended claims.

## Claims

1. An apparatus for dislodging or loosening mucus in a person's lungs, comprising a bath (24) arranged to receive the person (28) and a liquid (30) such that the person's chest is immersed in the liquid, means (10,12;34) for vibrating the liquid so that the vibrations are transmitted to the person's lungs, means (22) for detecting a level of vibrations to produce a detection signal, and means for attaching the detecting means to the person's chest so as to detect a level of the vibrations transmitted to the person's lungs, **characterized by** means (20) responsive to the detection signal for automatically adjusting the frequency of the vibrations produced by the vibrating means so that the frequency of the vibrations approximates a resonant frequency of the person's lungs and so as to maximise the level of the detected signal.
2. An apparatus as claimed in claim 1, wherein the adjusting means is arranged to adjust the frequency of the vibrations to such a resonant frequency in the range of 40 to 160 Hz.
3. An apparatus as claimed in claim 1, wherein the adjusting means is arranged to adjust the frequency of the vibrations to the Helmholtz resonant frequency of the person's lungs.
4. An apparatus as claimed in any preceding claim,

- wherein the vibrations are substantially sinusoidal.
5. An apparatus as claimed in any preceding claim, wherein the detecting means comprises a liquid-proof accelerometer (22).
  6. An apparatus as claimed in any preceding claim, wherein the vibrating means is disposed, in use, in front of or behind the person's chest.
  7. An apparatus as claimed in any preceding claim, wherein the vibrating means is disposed inside the bath.
  8. An apparatus as claimed in any of claims 1 to 6, wherein the vibrating means is disposed outside the bath and is arranged to transmit the vibrations to the liquid through a wall of the bath.
  9. An apparatus as claimed in any preceding claim, wherein the bath is arranged so that the person can sit up in the bath, and the vibrating means is disposed to one side of the bath.
  10. An apparatus as claimed in any of claims 1 to 8, wherein the bath is arranged so that the person can lie in the bath, and the vibrating means is disposed at the bottom of the bath.

#### Patentansprüche

1. Vorrichtung zum Verdrängen oder Lösen von Schleim in der Lunge einer Person mit einem Bad (24), das so angeordnet ist, daß es die Person (28) und eine Flüssigkeit (30) aufnimmt, daß der Brustkasten der Person in die Flüssigkeit eingetaucht wird, einer Einrichtung (10, 12; 34) zum Vibrieren der Flüssigkeit, daß die Vibrationen auf die Lunge der Person übertragen werden, einer Einrichtung (22) zur Feststellung einer Vibrationsstärke, um ein Feststellungssignal zu erzeugen, und einer Einrichtung zur Befestigung der Feststellungseinrichtung an dem Oberkörper der Person, um so eine Stärke der auf die Lunge der Person übertragenen Vibrationen festzustellen, **gekennzeichnet durch** eine Einrichtung (20), die auf das Feststellungssignal unter automatischer Einstellung der Frequenz der **durch** die Vibrationseinrichtung erzeugten Vibrationen derart, daß die Frequenz der Vibrationen einer Resonanzfrequenz der Lunge der Person nahekommt, reagiert, und daß die Stärke des ermittelten Signals maximiert wird.
2. Vorrichtung nach Anspruch 1, worin die Einstelleinrichtung so angeordnet ist, daß die Frequenz der Vibrationen auf eine solche Resonanzfrequenz im Bereich von 40 bis 160 Hz eingestellt wird.

3. Vorrichtung nach Anspruch 1, worin die Einstelleinrichtung so angeordnet ist, daß die Frequenz der Vibrationen auf die Helmholtz-Resonanzfrequenz der Lunge der Person eingestellt wird.
4. Vorrichtung nach einem der vorausgehenden Ansprüche, bei der die Vibrationen im wesentlichen sinusförmig sind.
5. Vorrichtung nach einem der vorausgehenden Ansprüche, bei der die Feststellungseinrichtung eine flüssigkeitsabweisende Beschleunigungsmeßeinrichtung (22) umfaßt.
6. Vorrichtung nach einem der vorausgehenden Ansprüche, bei der die Vibrationseinrichtung bei der Verwendung vor oder hinter dem Brustkorb der Person angeordnet ist.
7. Vorrichtung nach einem der vorausgehenden Ansprüche, bei der die Vibrationseinrichtung im Inneren des Bades angeordnet ist.
8. Vorrichtung nach einem der Ansprüche 1 bis 6, bei der die Vibrationseinrichtung außerhalb des Bades und so angeordnet ist, daß die Vibrationen durch eine Wand des Bades auf die Flüssigkeit übertragen werden.
9. Vorrichtung nach einem der vorausgehenden Ansprüche, bei der das Bad so angeordnet ist, daß die Person aufrecht in dem Bad sitzen kann, und die Vibrationseinrichtung an einer Seite des Bades angeordnet ist.
10. Vorrichtung nach einem der Ansprüche 1 bis 8, bei der das Bad so angeordnet ist, daß die Person in dem Bad liegen kann, und die Vibrationseinrichtung am Boden des Bades angeordnet ist.

#### Revendications

1. Appareil pour déloger ou décoller le mucus dans les poumons d'une personne, comprenant une baignoire (24) conçue pour recevoir la personne (28) et un liquide (30) de manière que la poitrine de la personne soit immergée dans le liquide, des moyens (10, 12 ; 34) pour faire vibrer le liquide de manière que les vibrations soient transmises aux poumons de la personne ; un moyen (22) pour détecter un niveau de vibrations afin de produire un signal de détection, et un moyen pour fixer le moyen de détection à la poitrine de la personne afin de détecter le niveau des vibrations transmises aux poumons de la personne, **caractérisé par** un moyen (20) répondant au signal de détection pour ajuster automatiquement la fréquence des vibrations pro-

duites par le moyen de vibration de manière que la fréquence des vibrations s'approche d'une fréquence de résonance des poumons de la personne et afin de porter à un maximum le niveau du signal détecté.

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2. Appareil selon la revendication 1, dans lequel le moyen d'ajustement est conçu pour ajuster la fréquence des vibrations à une telle fréquence de résonance dans la plage de 40 à 160 Hz. 10
3. Appareil selon la revendication 1, dans lequel le moyen d'ajustement est conçu pour ajuster la fréquence des vibrations à la fréquence de résonance de Helmholtz des poumons de la personne. 15
4. Appareil selon l'une quelconque des revendications précédentes, dans lequel les vibrations sont sensiblement sinusoïdales. 20
5. Appareil selon l'une quelconque des revendications précédentes, dans lequel le moyen de détection comprend un accéléromètre (22) étanche aux liquides. 25
6. Appareil selon l'une quelconque des revendications précédentes, dans lequel le moyen de vibration est disposé, en service, devant ou derrière la poitrine de la personne. 30
7. Appareil selon l'une quelconque des revendications précédentes, dans lequel le moyen de vibration est disposé à l'intérieur de la baignoire. 35
8. Appareil selon l'une quelconque des revendications 1 à 6, dans lequel le moyen de vibration est disposé à l'extérieur de la baignoire et est conçu pour transmettre les vibrations au liquide à travers une paroi de la baignoire. 40
9. Appareil selon l'une quelconque des revendications précédentes, dans lequel la baignoire est conçue de manière que la personne puisse s'asseoir dans la baignoire, et le moyen de vibration est disposé sur un côté de la baignoire. 45
10. Appareil selon l'une quelconque des revendications 1 à 8, dans lequel la baignoire est conçue de manière que la personne puisse s'allonger dans la baignoire, et le moyen de vibration est disposé sur le fond de la baignoire. 50

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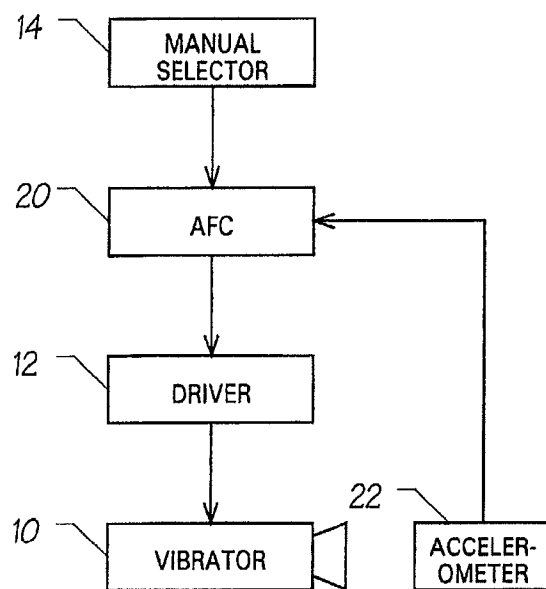


FIG. 1

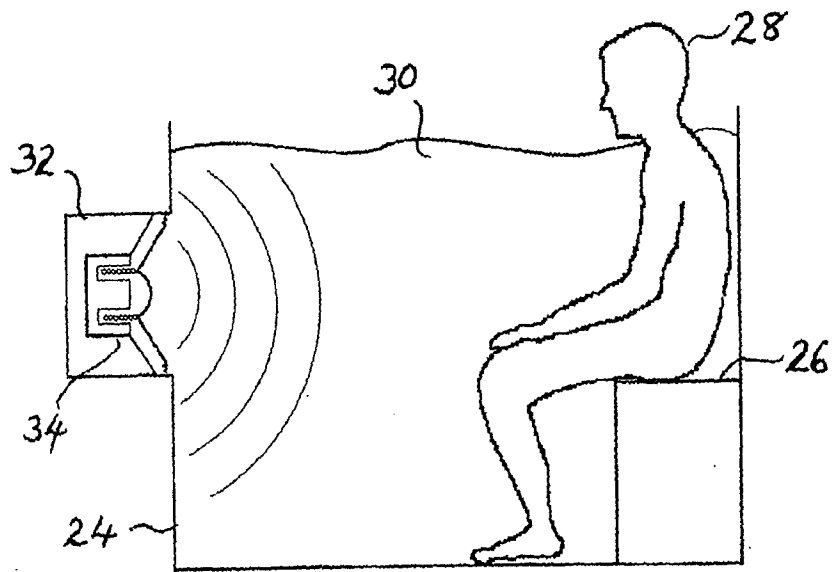


FIG. 2

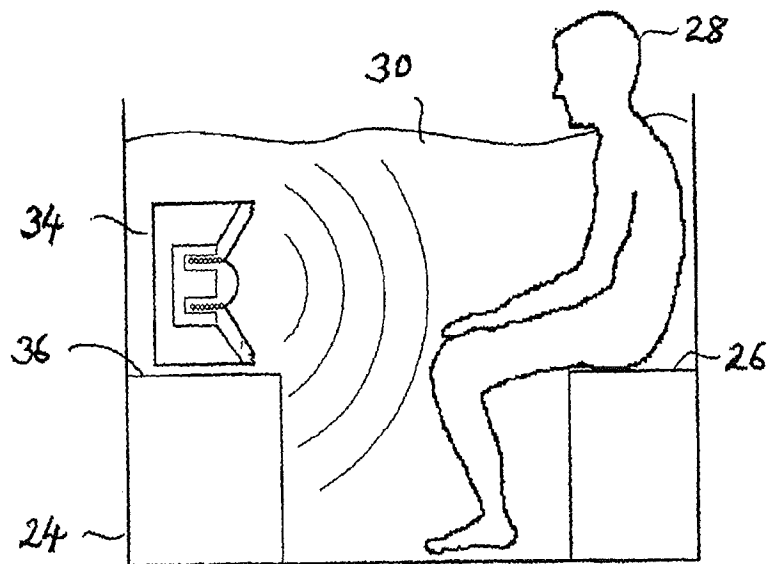


FIG. 3

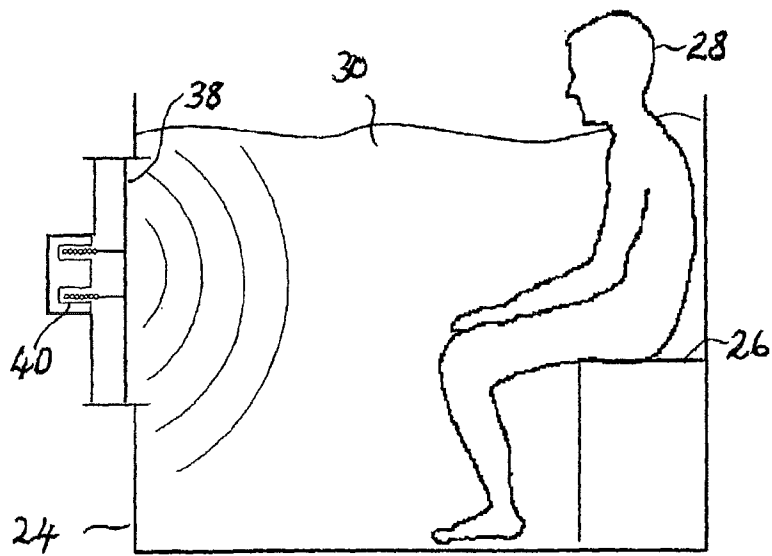


FIG. 4

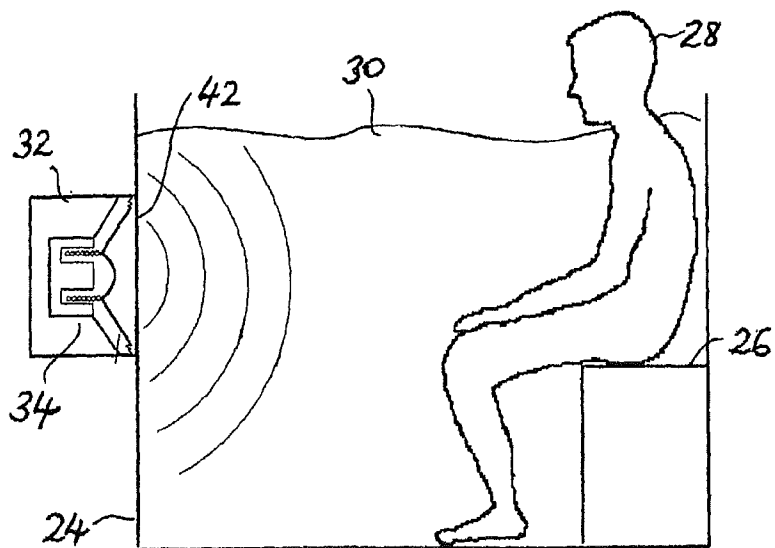


FIG. 5